Effects of Land-Atmosphere Coupling Strength and Soil Moisture Initialization Uncertainty on Subseasonal Rainfall and Temperature Prediction

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Project goal/contribution: Comprehensive analyses of (a) controls over land-atmosphere coupling strength in atmospheric models and (b) translation of soil moisture initialization uncertainty into precipitation and temperature forecast uncertainty.

Objectives & deliverables:

- Improved understanding of the physics underlying land-atmosphere coupling strength in AGCMs
- Guidelines for improving the simulation of land-atmosphere coupling strength in AGCMs
- Quantification – using a state-of-the-art AGCM – of the degree to which uncertainty in soil moisture initial conditions can foil a forecast
- Development/optimization of an experimental approach toward this quantification that can be used by any modeling system, including the final NEWS system.

Technical approach and/or methods:

- Land-atmosphere coupling strength:

  -- utilization of indirect “observational” measures

  -- comprehensive single column model simulations.
- Uncertainty translation:

  -- processing of satellite-data specific uncertainty levels

  -- huge (200-member) forecast simulations, following strategy of Koster et al. (2004).

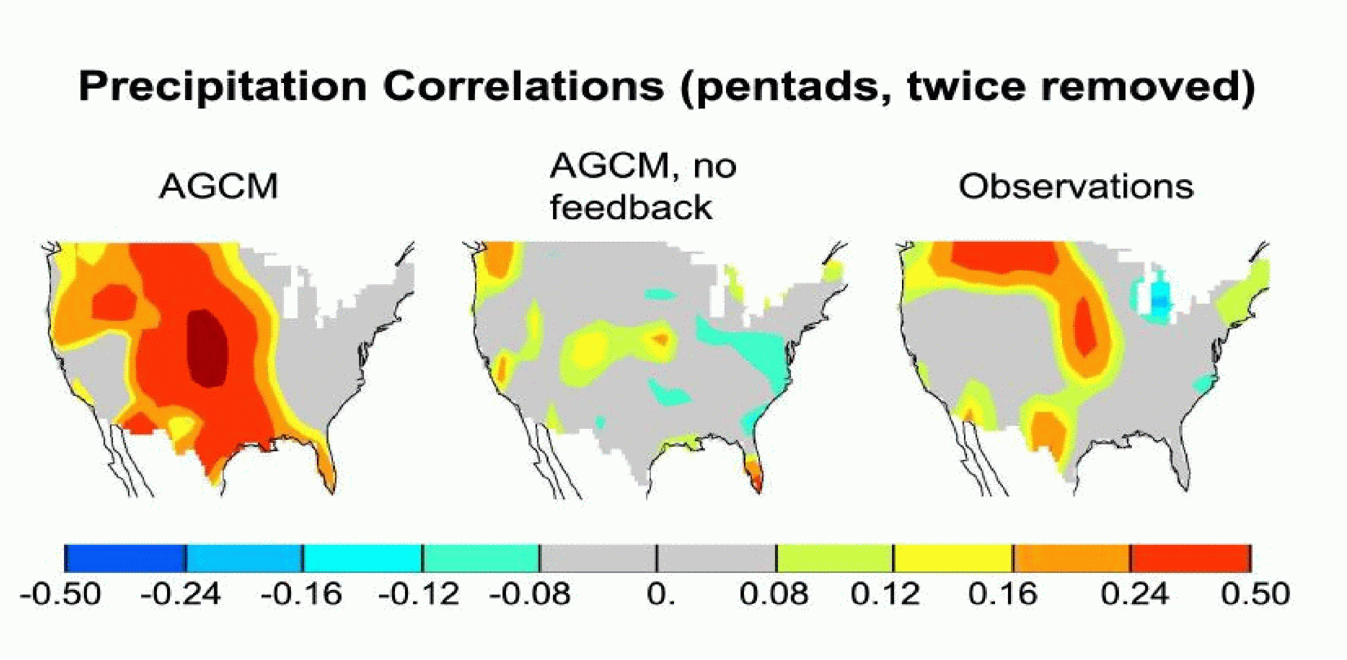
(see accompanying slides)

Part 1

Improve the simulation of land-atmosphere coupling in an AGCM

Key problem: direct estimates of land-atmosphere coupling strength in the real world do not exist –
How do we know what's "correct"?

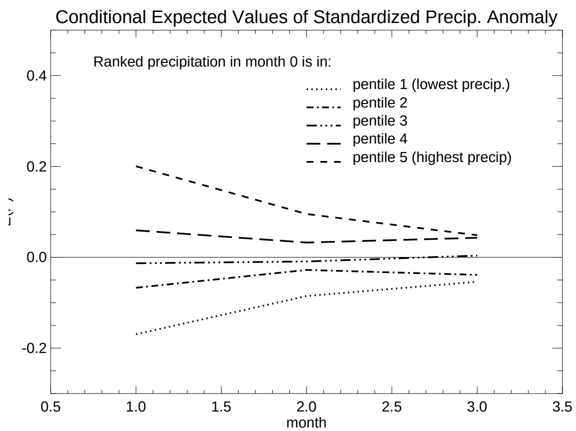
Solution: utilize *indirect* estimates of coupling strength.

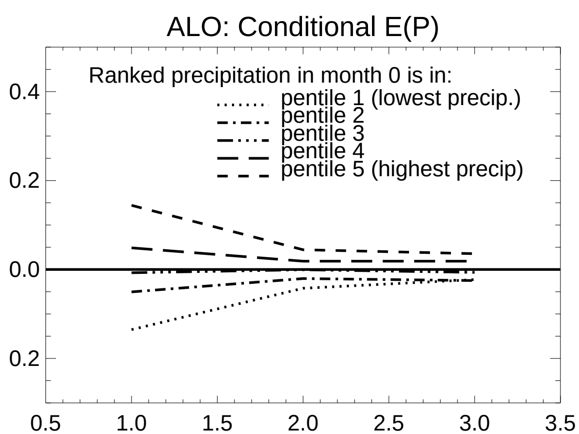


Lagged autocorrelations of precipitation: modeled (NSIPP AGCM) and observed.

Koster et al., GRL, 30(5), 1241, doi:10.1029/2002GL016571, 2003.

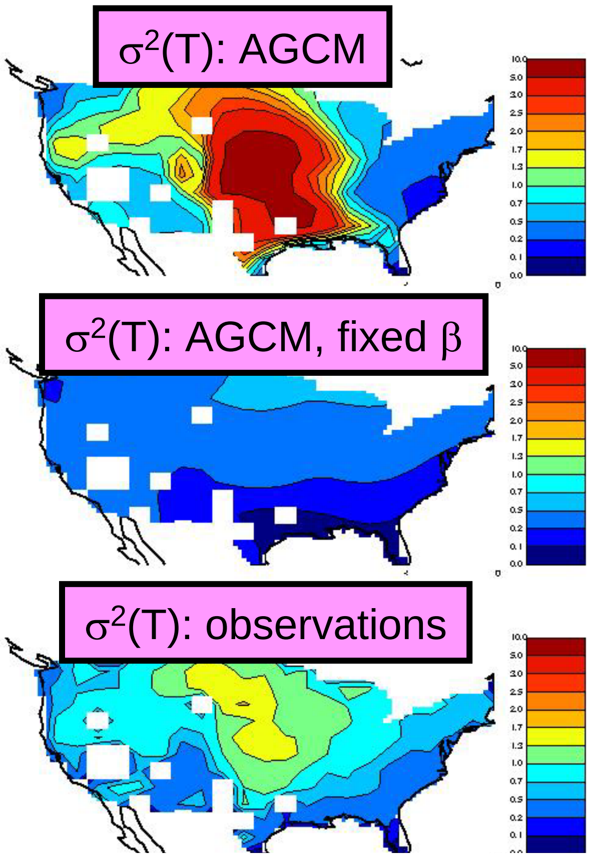
More indirect measures





Conditional expected value of monthly rainfall

Koster and Suarez, J. Hydromet., 5, 567-572, 2004.



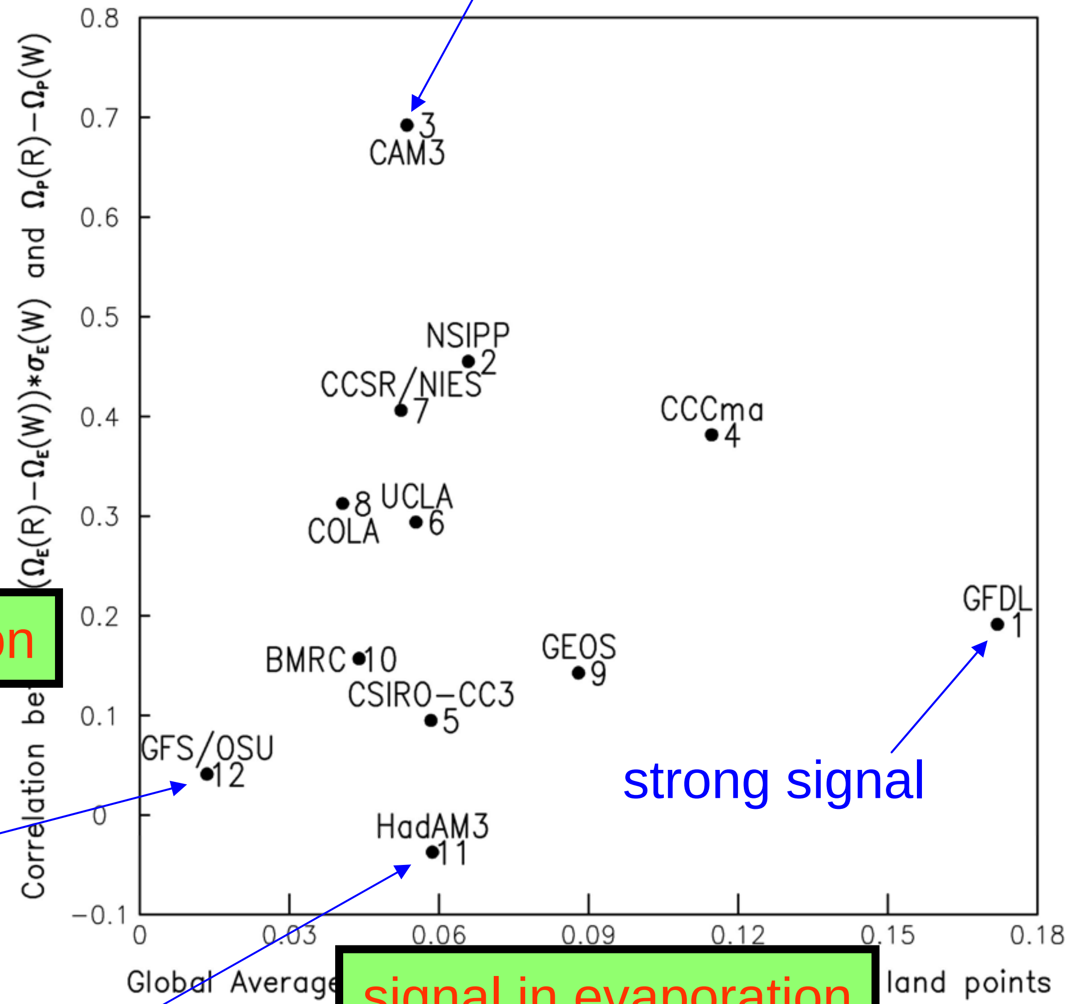
Temperature variance

Koster et al., J. Hydromet., submitted.

How do we improve coupling strength?

Step 1: Utilize what we’ve learned from GLACE.

efficient transmission



signal transmission

strong signal

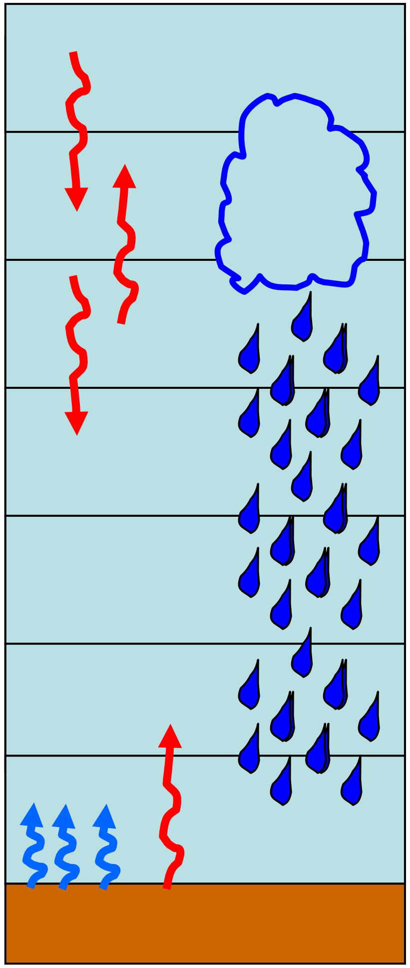
weak signal

signal in evaporation

inefficient transmission

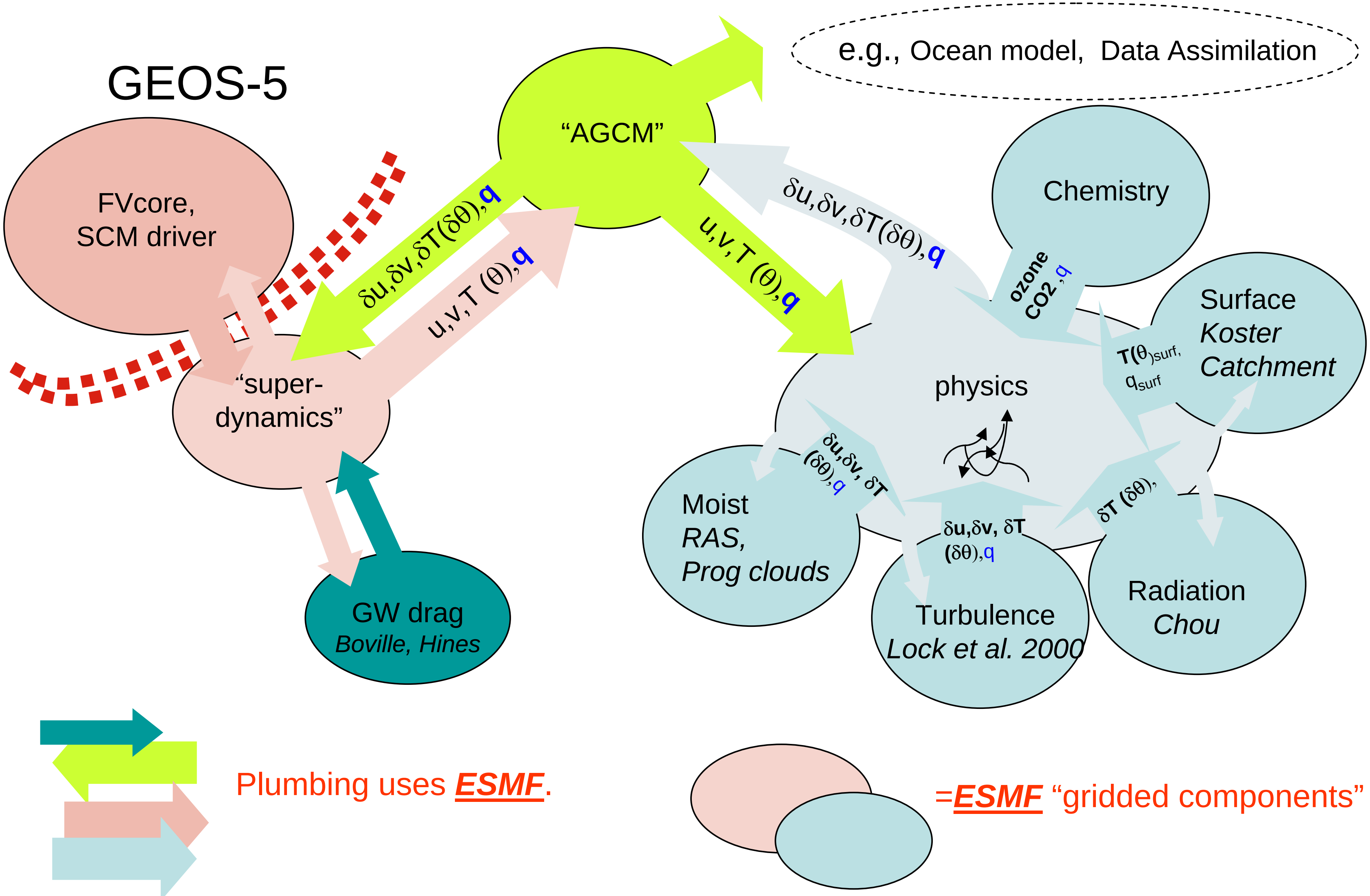
Guo et al., J. Hydromet., submitted.

Step 2: Perform a series of sensitivity simulations utilizing a single-column version of the AGCM.



Test impact of details of:
-- convective parameterization
-- boundary layer parameterization
-- land surface parameterization
on responsiveness of simulated precipitation

➔ A comprehensive overview of what controls coupling strength in an AGCM – an overview that should have broad relevance to AGCMs in general.

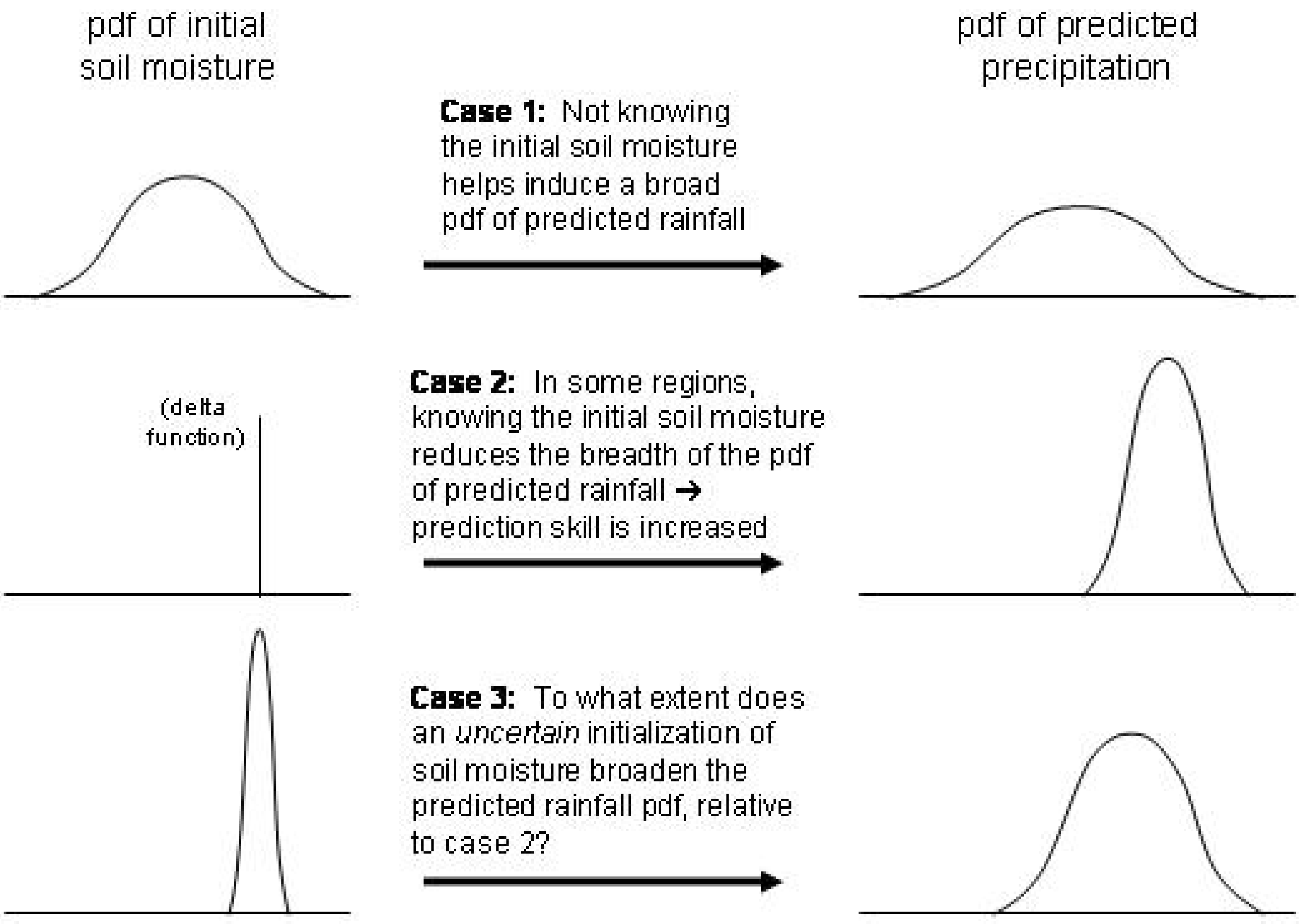


SCM version of GEOS-5 exists

SCM and full AGCM structurally identical – distinction occurs only at run-time and is based on initialization files, compiler switch.

Part 2

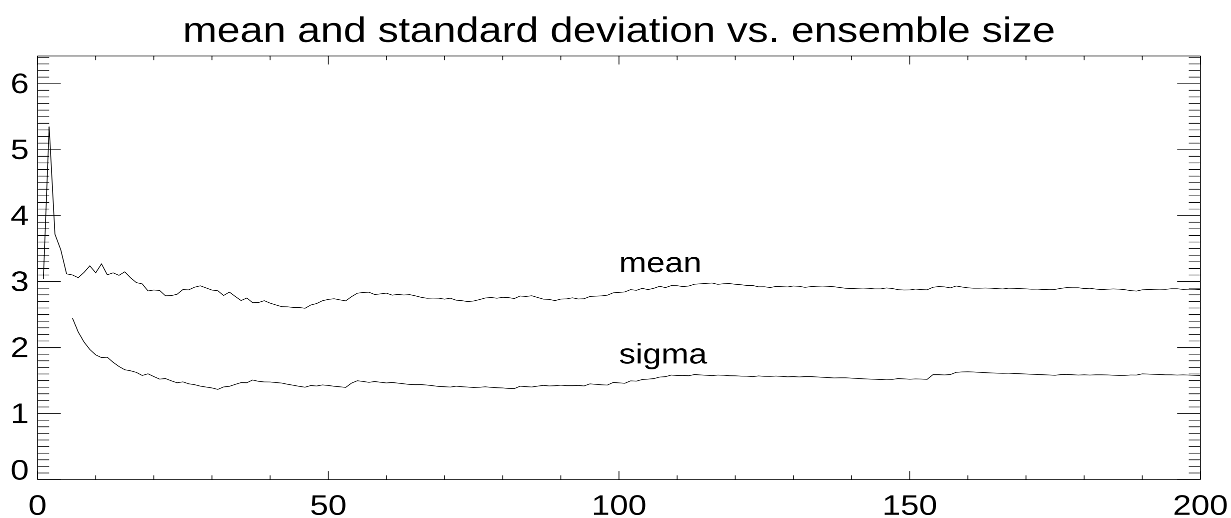
Impact of initialization uncertainty on precipitation forecasts

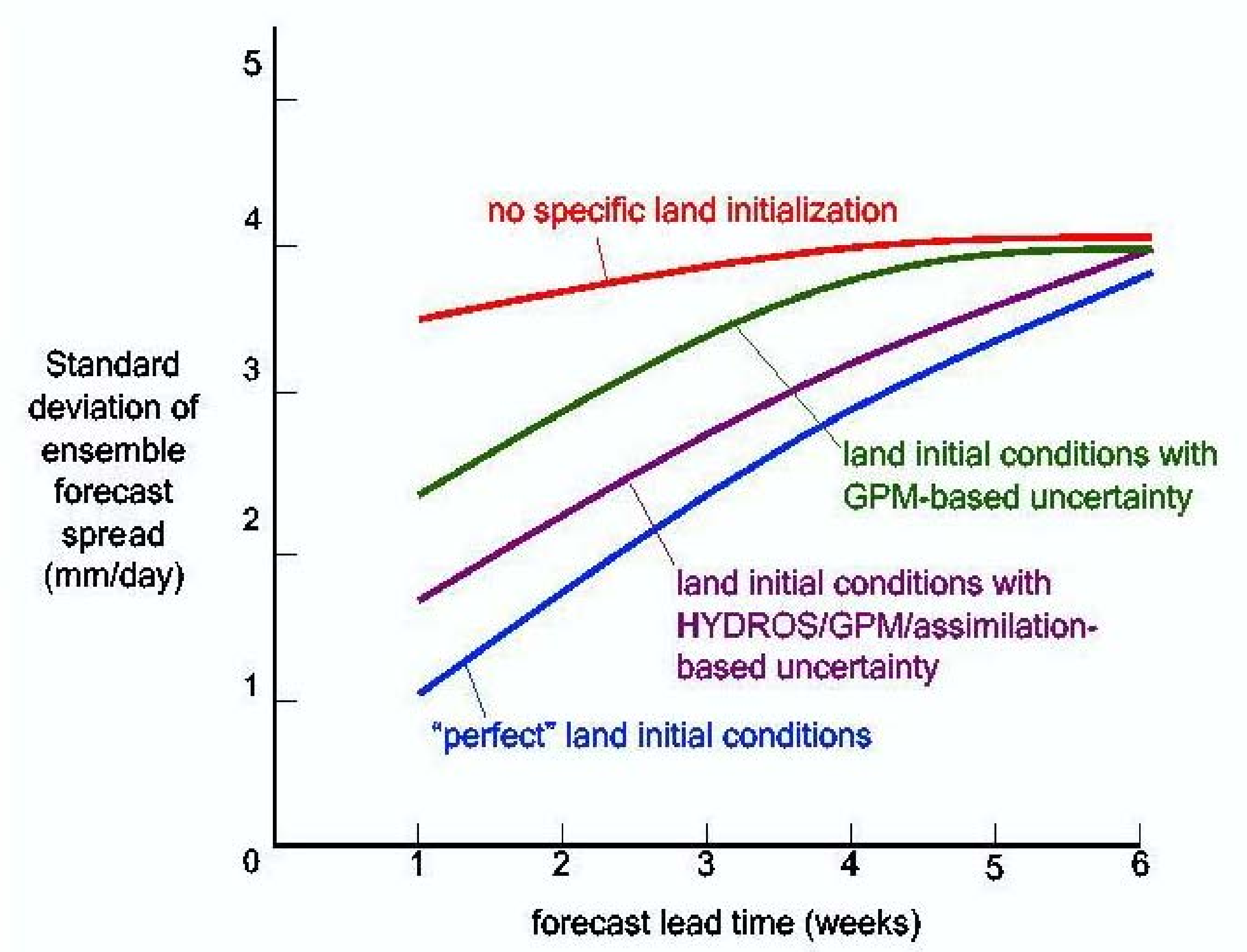


How much error in the land conditions is acceptable before the spread in the forecasts becomes too large, making land initialization useless? No one has ever quantified this.

We quantify this impact of uncertainty through forecasting experiments involving huge ensembles (200 members), following the strategy of Koster et al (2004).

	1986	1988	1993
"Perfect" knowledge of soil moisture (no error)	✓	✓	✓
Error stemming only from non-precip. forcing	✓	✓	✓
Error consistent with GPM retrievals	✓	✓	✓
Error consistent with GPM +AMSR retrievals	✓	✓	✓
Error consistent with GPM +HYDROS retrievals	✓	✓	✓
No knowledge of soil mois-ture (climatological pdf)	✓	✓	✓





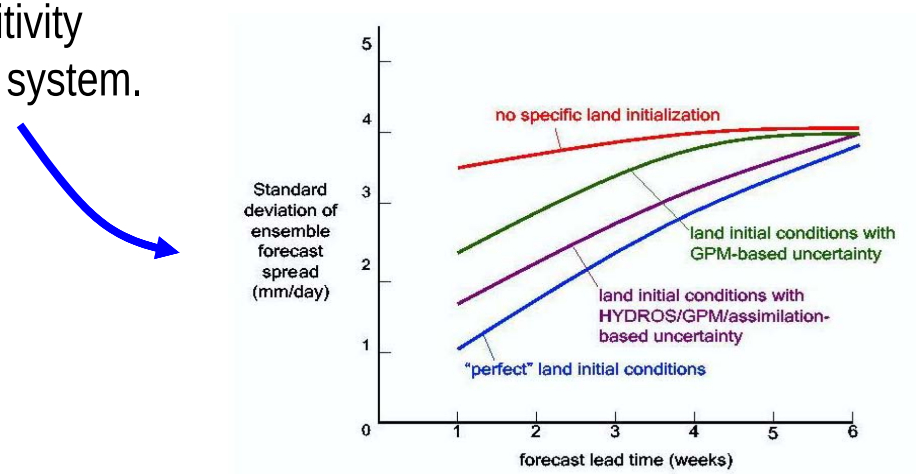
Our goal is a plot of forecast uncertainty as a function of land surface initialization uncertainty – along with a "debugged" approach for generating it.

Data set needs:

(No independent large data sets needed, other than those already stored at GMAO. Storage of AGCM data managed under existing GSFC frameworks.)

Project outputs:

- Guidelines for characterizing and improving land-atmosphere coupling strength in AGCMs.
- Guidelines for characterizing the sensitivity of subseasonal forecasts to uncertainty in initial land surface state.
- Quantification of this sensitivity using a state-of-the-art forecast system.



Potential collaborations (with NSIT, other NEWS projects, etc.) **:**

-- NEWS model structure

--Latent heating profiles, precipitation uncertainty estimates, boundary layer studies, land surface model parameterizations, other coupling studies.

Important outside linkages/resources (outside the NEWS team) **:**

- Land-atmosphere coupling strength analysis will include analysis of NCEP system, shown in GLACE to have minimal (and unrealistic) coupling strength.
- Uncertainty analysis: GPM, Hydros, SMOS, AMSR, …

Expected contribution to the NEWS objective:

- “Building a fully interactive global climate model that encompasses the process-level forcings on and feedbacks within the global energy and water cycle” – improvements in the understanding and treatment of land-atmosphere coupling strength.
- “Supporting the application of climate prediction capabilities for estimating the impact of climate variability and climate changes on water resources over a variety of spatial and temporal scales” – characterization of the impacts of soil moisture initialization uncertainty on predictability.

Issues, needs, and concerns (to be discussed in breakouts, teaming discussions, etc.):

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-
-

(additional background)

Two parts to the proposed work:

1. Improve the treatment of land-atmosphere coupling in an AGCM.

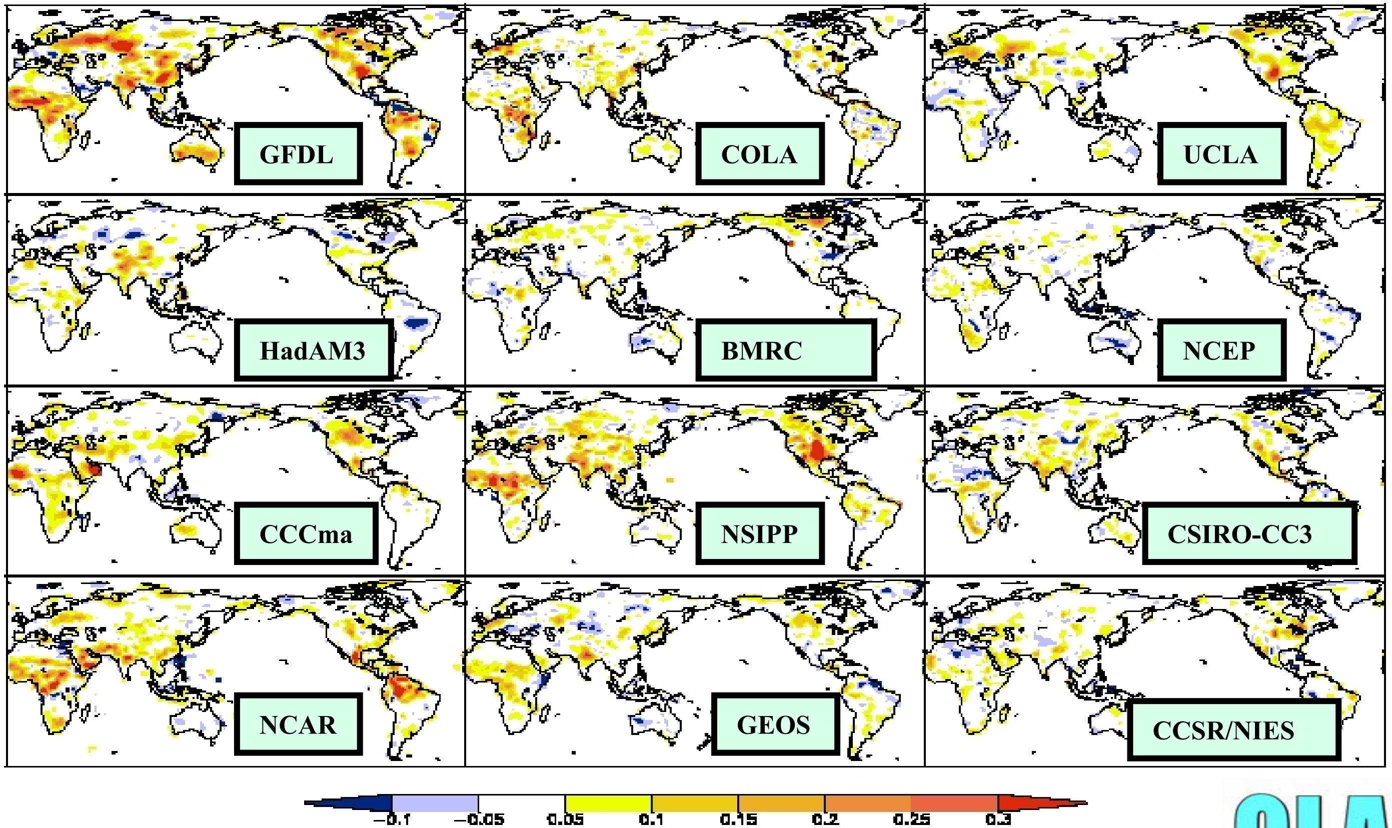
2. Quantify the degree to which uncertainty in surface conditions (as related, for example, to errors associated with satellite-derived soil moisture contents) translate into uncertainty in precipitation forecasts.

Project summary:

1. Comprehensive analysis of what controls land-atmosphere coupling strength in a typical model.

2. Once we've optimized the model's coupling strength, comprehensive study of how soil moisture uncertainty translates into precipitation and temperature forecast uncertainty.

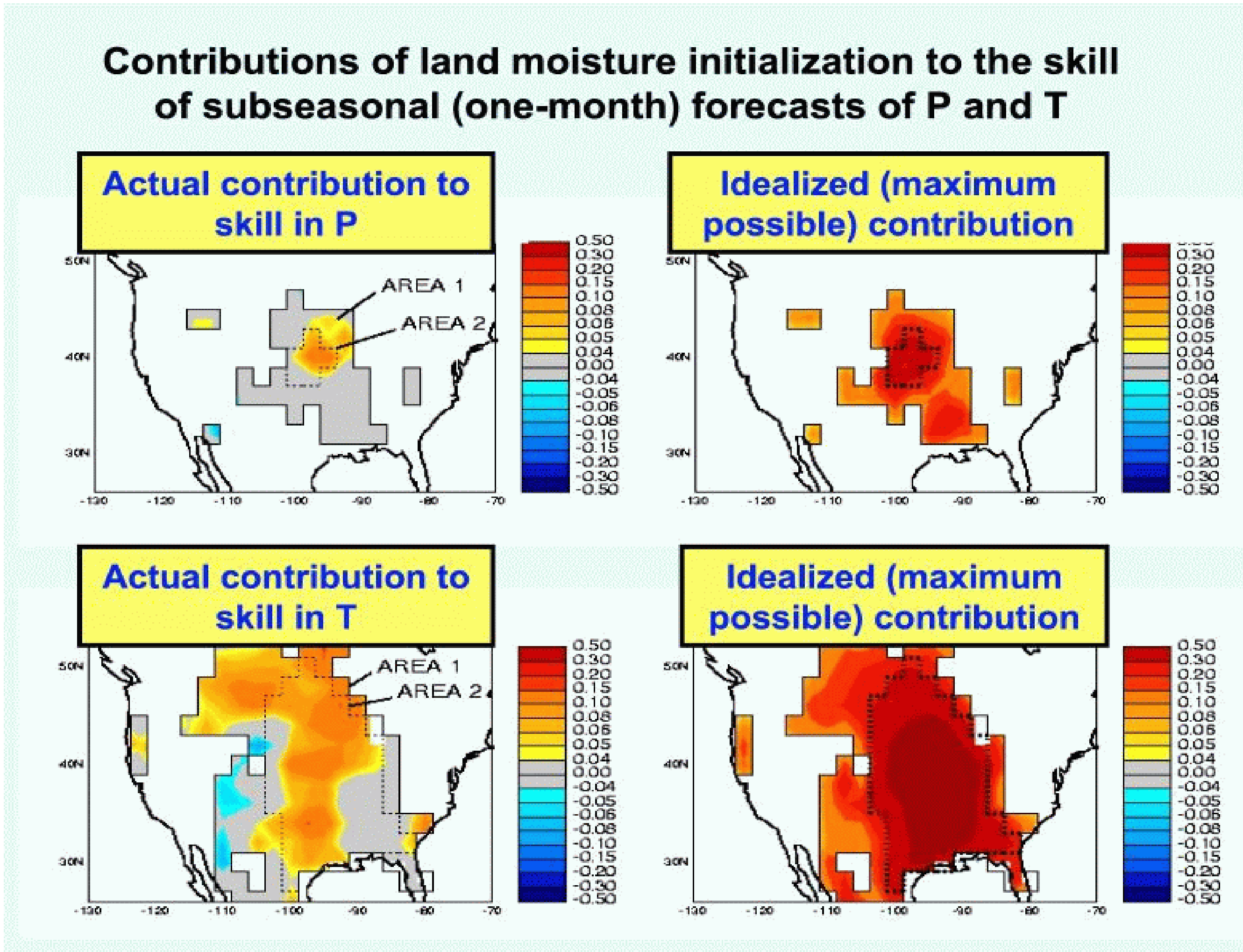
Ω_p (S - W): Impact of sub-surface soil moisture on precipitation



First note: the GLACE project found that AGCMs differ markedly in their simulation of coupling strength.

Koster et al., J. Hydrometeorology, submitted.

Evidence that the realistic initialization of land surface moisture reservoirs improves subseasonal precipitation and temperature forecasts has been obtained with the NSIPP (GMAO) forecast system.



Koster et al., J. Hydromet., 5,1049-1063, 2004.